PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO SYNCHRONOUS MOTORS

(71) We, COMPAGNIE ELECTRO-MECHANIQUE, a French corporate body, of 12 rue Portalis, 75008 Paris, France, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention concerns improvements in or relating to synchronous motors.

In various industrial fields there is a requirement for high rotational speeds preferably produced directly by means of appropriate motors, commonly of the self-synchronizing synchronous motor type at least if the rotational speed is required to be precise. Above 3,000 r.p.m. (or 3,200 in the case of 60 cycle local supply circuits) a static source of supply should be provided, with a fixed or variable frequency. It follows that the characteristics of the motors (output, power factor, starting current) have a strong effect on the cost of the installation. Moreover, such high speed motors should comprise a robust rotor having an excellent mechanical behaviour.

One object of the present invention is to enable the construction of self-synchronizable synchronous motors adapted to operate at very high speeds with excellent mechanical and electrical characteristics.

According to the present invention there is provided a synchronous motor rotor comprising a plural-armed central body member, plate-like permanent magnets applied against lateral faces of the arms of the body member and pole pieces of magnetic material disposed between the said arms so as to be applied against the surfaces of the magnets remote from said arms, a cage conductor permitting starting of the motor being provided in slots in the extremities of the arms of the body member and/or in the pole pieces, wherein the rotor is axially divided into a plurality of axially contiguous elemental rotors, each elemental rotor being housed between two respective side members appropriately slotted to allow the passage of the cage bars, the pole pieces of each elemental rotor being traversed by fixing members which likewise pass through the side members to hold the elemental rotor together.

The holding in position of the various constituent parts of each elemental rotor is effected by providing, at the ends of the assembly of body, magnets and pole pieces, two side members adapted to withstand the centrifugal forces exerted on the pole pieces and on the magnets, and connecting these side members to one another by means of longitudinal fixing members passing through the pole pieces, these side members being, moreover, cut out with peripheral slots provided and disposed in such a manner as to correspond with those in the spider and the pole pieces with a view to permitting the passage of the bars of the cage. The longitudinal fixing members may advantageously be constructed in the form of rivets.

In order to limit the length of the fixing members or rivets, particularly in the case of motors adapted to rotate at very high speeds, the rotor is divided into a plurality of successive elements each with two lateral side members, these elements being fixed against one another in the axial direction.

This division of the rotor also has the following very important advantage.

It is known that for satisfactory operation, it is preferable to incline the stator slots in relation to the rotor slots and poles. Now in the conventional machines, in order to wind the stators it is practically impossible to work with slots inclined in relation to the generatrices. The inclination must therefore necessarily be transferred to the rotor. But in the case of a rotor of the kind described, such an inclination would lead to the use of magnets of a curved shape adapted to the inclination, which would be difficult and expensive.

These difficulties can be easily resolved by the division of the rotor. It is actually

sufficient to offset slightly the successive elements of this and to make the bars of the cage by casting in the slots which are thus not perfectly aligned. This offsetting may advantageously be distributed between the side members and the assemblies which they surround in the sense that the slots of each side member are very slightly offset in relation to those in the pole pieces and the spider, so that the angle of offsetting provided between two successive elemental rotors is effected by means of two successive angular offsettings of half the total. Thus the local constriction of the section of the bars caused by the offsetting is reduced to a negligible value.

Each side member may advantageously comprise holes adapted to receive the heads of the rivets associated with the adjacent side member, thus ensuring the correct indexing of the successive elements. By judicious provision of the arrangement of these holes and of those adapted for the passage of the rivets, it is moreover possible to achieve that a single type of side member can be used for the construction of the rotor.

In order than the invention might be clearly understood, two exemplary embodiments thereof will now be described with reference to the accompanying drawings wherein:—

Figure 1 is a cross section of an elemental rotor of a rotor according to the invention, produced in laminated form.

Figure 2 shows a lateral side member of such an elemental rotor.

Figure 3 shows this same side member turned through 180° about a diametral axis N—N or S—S.

Figure 4 is a plan view with parts broken away, representing a rotor made of a plurality of elements comprising side members as shown in Figures 2 and 3.

Figure 5 is a section of another form of embodiment of a rotor device according to the invention.

Figure 6 is a partial longitudinal section of this.

Figure 7 is a detail view showing a lateral side member with a folding tab for holding a magnet.

The elemental rotor illustrated in cross section in Figure 1 comprises a rotor body or spider made of four arms 1 rigidly connected to a central portion 2 suitably perforated at 3 for the passage of the shaft, this spider 1—2 being constructed in laminated form by stacking suitably cut out laminations of magnetic material. It will be noted that the arms 1, made trapezoidal, comprise towards their external end (which corresponds to the circular periphery of the rotor) slots 4 which are shown closed but which may likewise alternatively be open. This arcuate end of each arm 1 is integral with two lateral noses 5.

Disposed against each of the lateral faces of each arm 1 is a flat permanent magnet 6, magnetized through its thickness, as indicated by the letters arrows S and N which correspond to the south and north polar faces. As Figure 1 clearly shows, the facing polarities of the arm 1 under consideration are opposite. These magnets are thus retained by the noses 5 and by a non-magnetic key 7 of triangular section disposed at the bottom of the space in the form of an obtuse angle which separates the successive arms 1. It should be noted, moreover, that the key 7 could be omitted if the facing facets of the magnets were provided at an angle so that they fitted one against the other.

Finally, disposed against the faces of the magnets opposite to the arms 1 are pole pieces 8 of magnetic material in the form of a triangle with an obtuse apex angle and a base rounded in an arc of the desired radius for the rotor and which corresponds to that of the ends of the arms of the spider, these pieces, also made in laminated form, comprising peripheral slots 9 similar to those 4 of the arms 1 of the spider 1—2. The pieces 8 are perforated with four holes, namely two holes 10 situated on the radial polar axis corresponding to the piece in question and two others 11 disposed on an arc concentric with the rotor, at each side of the aforesaid axis.

It will be noted that the two magnets 6 adjacent to one and the same pole piece 8 present to this faces of the same polarity so that if the periphery of the rotor is followed, a north pole piece, then a south pole piece, then another north and finally a second south are found alternately, the whole forming an assembly with two polar axes N—N, S—S and four poles.

The assembly described above is surrounded by two lateral side members connected to one another by rivets such as 12, which pass, more or less with a force fit, through some of the holes 10 and 11, these side members being perforated with peripheral slots which correspond to those 4 and 9 in the said assembly, the whole as will be described in more detail later.

Finally, the bars of a squirrel cage are disposed in the slots 4 and 9, these bars (not illustrated in Figure 1) passing through the slots in the lateral side members to end, in known manner, at two short-circuit rings provided against the outer face of the side members.

It will be understood that when a rotor formed by an assembly of elemental rotors thus produced is mounted in a corresponding wound stator, a synchronous machine is, in fact, produced with

permanent magnets and a squirrel cage, adapted to start as an induction motor then to become synchronized with the rotating field of the stator when the speed reached is sufficient. The magnets 6, the mass of which is relatively small, are perfectly held against the centrifugal force by the noses 5 and the pole pieces 8, which are in turn held by the rivets and the lateral side members and in part by the cage. This fixing may advantageously be supplemented by sticking the magnets to the arms 1 and to the pieces 8, or by impregnating them with suitable resins.

Of course, in such an assembly, it is an advantage to make the rivets 12 of as short a length as possible. For this purpose, the rotor is divided in the form of a plurality of elemental rotors disposed one against the other, for example by mounting with a force fit on the shaft, each comprising its two side members and its assembly rivets. It is then possible to offset angularly these successive elemental rotors by a small angle in such a manner as ultimately to produce the equivalent of a conventional rotor with slots orientated obliquely in such a manner that for each one, one of the ends is offset by one step in relation to the other.

Figures 2 to 4 illustrate such an arrangement. It will be noted that here one pair of holes 16 of the side member 14 arranged to correspond with holes 10 in the pole pieces 8, is offset by a small angle α in relation to the polar axis N—N or S—S, while the pair of holes 15 adapted to correspond to the holes 11 in the pieces 8 is offset by the same angle α but in the opposite direction. It will further be noted that in each group of two holes 15 and of two holes 16, the diameter of the holes of one of the pairs is larger than that of the holes of the other pair, the arrangement being reversed on passing from one group to the next, rotating about the central axis of the rotor. It is easy to verify that such an arrangement leads to the following results:

1) If an elemental rotor such as A (Figure 4) is surrounded by two side members 14 which are identical but reversed by rotation through 180° about the diametral axis N—N or S—S in relation to one another (relative arrangement of Figures 2 and 3), the slots such as 13 of the side members are offset by an angle equal to 2α.

2) If two elemental rotors B and C, which are identical to one another except that the side members of one are offset by 90° about the motor axis from the positions of Figures 2 and 3 in relation to the assembly of the spider and the pole pieces, are disposed following one on the other, the heads 17 of the rivets 12 of the one will be accommodated in the large-diameter holes 15 (or 16) of the adjacent side member of the other when the slots of the two side members are aligned, which guarantees the correct indexing of the two elemental rotors in question.

3) In the complex rotor finally obtained, each slot represents a passage in a successive staircase of small dimensions which, if the elemental angle α has been selected judiciously, constitutes the equivalent to an oblique slot with ends offset by one step, the whole without any of the elemental offsettings corresponding to an appreciable constriction of the section of the slot.

In these circumstances, the bars 18 of the cage can easily be constructed by casting, while the stator is provided with longitudinal slots, which facilitates the mechanical winding.

Figures 5 to 7 show another form of embodiment of the invention for a motor with six poles. Here the rotor body or spider 2 obviously has six arms. It may be assumed that it is made of solid mild steel and that it is keyed onto the shaft or integral therewith, its construction in laminated form not being in any way excluded. The spaces which separate the successive arms of this spider have an arcuate profile and each of them receives a single permanent magnet 6 which may be regarded as the equivalent to two successive magnets in the previous form of embodiment. The pole pieces 8 are shaped to correspond; they are again held there by fixing members or rivets 12. Moreover, it has been assumed that the slots 4 were circular, in view of the fact that this profile is easier to form in a solid member. As indicated in Figure 6, the rotor comprises a series of elements of small width which, contrary to the case in Figures 1 to 4, are separated from one another by a small gap receiving the rivet heads of the fixing members 12. The bars 18 of the squirrel cage are rectilinear and are mounted in the slots instead of being cast *in situ*, as in the previous form of embodiment. One of the short-circuit rings is seen at 19. Of course, if it is desired the stator slots may be arranged obliquely to the rotor bars.

With such a construction, the magnets 6 may be slid into position after the pole pieces have been mounted. In order to hold them, a small tab 20 (Figure 7) may be provided on each side member 14, being delimited by two slits 21 and folded down over the end of the magnet in question once this has been mounted.

Moreover, it should be understood that the preceding description has only been given by way of example and that it in no way limits the scope of the invention which would not be departed from by replacing the details of embodiment described by any other equivalents. It will be understood that

there may be any number of poles. The orientation of the magnets could be selected so that the flux of the rotor passes through the ends of the arms of the spider and not through the intermediate members, said ends then being made wider for this purpose. The peripheral slots could be open. The fixing members could be constructed with threaded ends to receive nuts or in the form of screws screwing into one of the side members.

Of course, the electrical machine comprising a rotor device of the kind described above can function as an alternator, if desired.

WHAT WE CLAIM IS:—

1. A synchronous motor rotor comprising a plural-armed central body member, plate-like permanent magnets applied against lateral faces of the arms of the body member and pole pieces of magnetic material disposed between the said arms so as to be applied against the surfaces of the magnets remote from said arms, a cage conductor permitting starting of the motor being provided in slots in the extremities of the arms of the body member and/or in the pole pieces, wherein the rotor is axially divided into a plurality of axially contiguous elemental rotors, each elemental rotor being housed between two respective side members appropriately slotted to allow the passage of the cage bars, the pole pieces of each elemental rotor being traversed by fixing members which likewise pass through the side members to hold the elemental rotor together.

2. A rotor in accordance with claim 1 wherein each said side member includes, in addition to the holes for the passage of the fixing members for the elemental rotor with which it is associated, further holes of greater diameter to accept the heads of the fixing members of an adjacent elemental rotor, the arrangement of said further holes being different from that of the holes for the fixing members.

3. A rotor in accordance with claim 2 wherein said fixing members are arranged in a first and in a second array in alternate ones of said pole pieces, each of said pole pieces being perforated to accept fixing members in each of said arrays, the arrangement being such that when the heads of the fixing members of one elemental rotor are aligned with said further holes of an adjacent elemental rotor said elemental rotors are predeterminedly angularly offset.

4. A rotor in accordance with any one of the preceding claims and wherein successive elemental rotors are progressively angularly offset to provide a staircase-like succession of said slots and wherein the bars of said cage conductor extend in a continuous manner from one axial extremity to the other of the rotor without junction rings between successive elemental rotors.

5. A rotor in accordance with claim 4 wherein the angular offset between adjacent element rotors is less than the maximum angular extent of a said slot.

6. A rotor in accordance with claim 4 or claim 5 wherein the angular offset between two successive elemental rotors is distributed equally between on the one hand said rotor and on the other hand each of the side members by which it is bounded.

7. A rotor in accordance with claim 6 wherein all said side members are identical and each includes a first and a second major face, while each elemental rotor includes a first and a second side face, each said side member being pierced to receive said fixing members in such a manner that when each side member is applied with its first face against the first side face of an elemental rotor and is oriented in a manner allowing the insertion of the fixing members, the slots of this side member are offset in one direction by the desired angle with respect to the slots of the elemental rotor and when another said side member is applied with its second face against the second side face of the same elemental rotor, the slots in this other side member are offset with respect to those of the elemental rotor by the same amount and in the same sense, whereby the angular offset of the slots in the two side members with respect to one another is twice that of the slots in each side member with respect to those of the rotor element.

8. A rotor in accordance with claim 7 as dependent upon claim 3, 4, 5 and 6 wherein the array of said further holes in each side member is offset with respect to the holes for the fixing members by twice the angle of offset of the slots in the side member with respect to those of the elemental rotor with which the side member is associated and in the same sense, while in the laminations constituting the elemental rotor the arrays of perforations are not offset, whereby upon assembly of said elemental rotors each will be offset with respect to an adjacent said elemental rotor by an angle equal to that by which the two arrays of holes in said side members are offset.

9. A rotor in accordance with any one of the preceding claims wherein said magnets are retained by tab members formed

integrally with said side members at their peripheries.

10. A rotor in accordance with claim 1 and substantially as herein described with reference to the accompanying drawings.

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1552694 COMPLETE SPECIFICATION
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Sheet 1

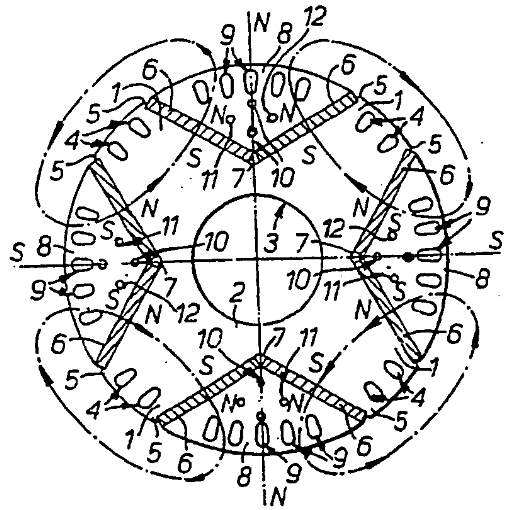

FIG. 1.

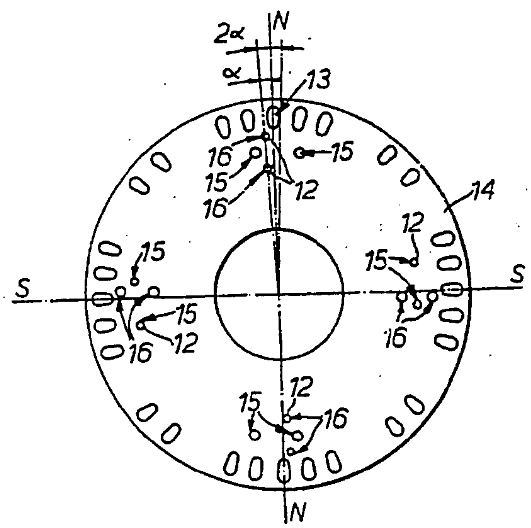

FIG. 2.

1552694 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

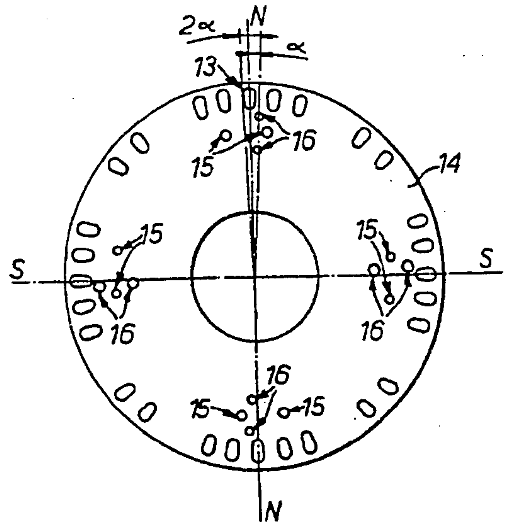

FIG. 3.

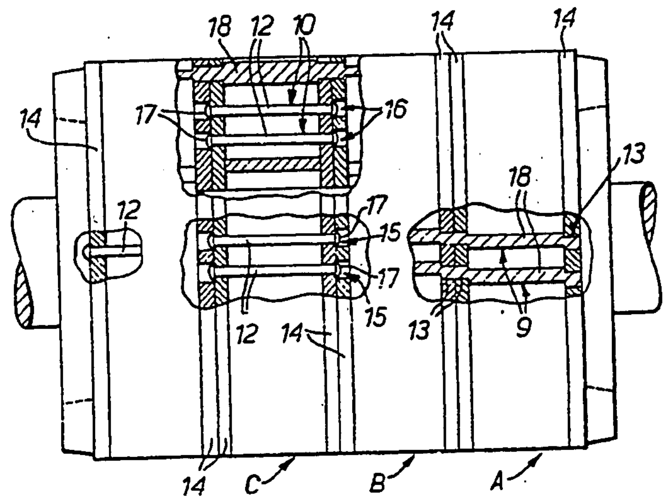

FIG. 4.

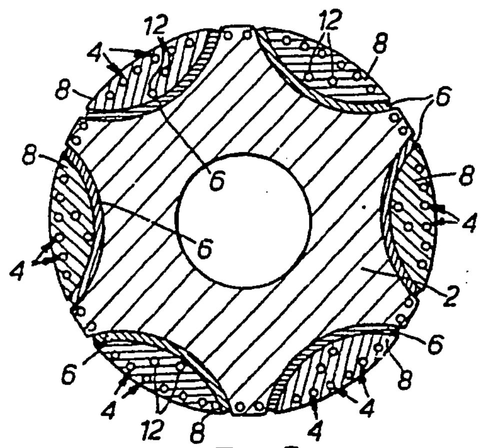

FIG.5.

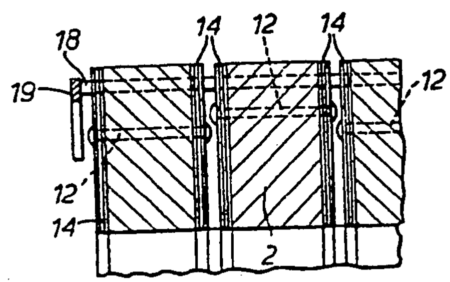

FIG.6.

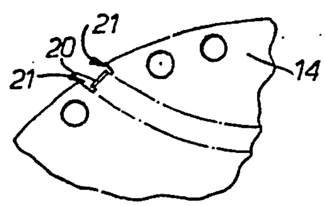

FIG.7.